A Controller-in-the-Loop Simulation of Ground-Based Automated Separation Assurance in a NextGen Environment

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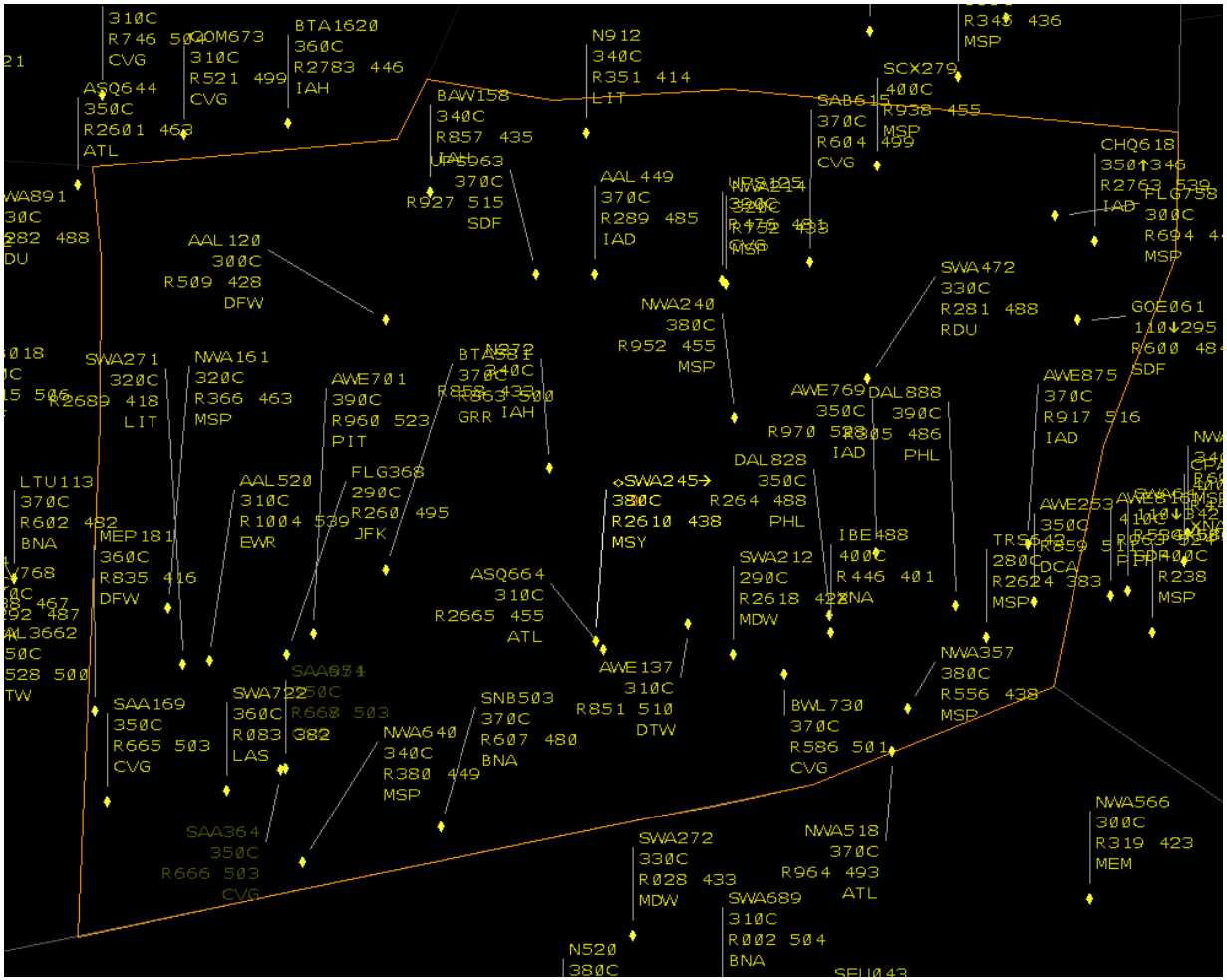
NASA Airspace Program

Federal Aviation Administration (FAA)

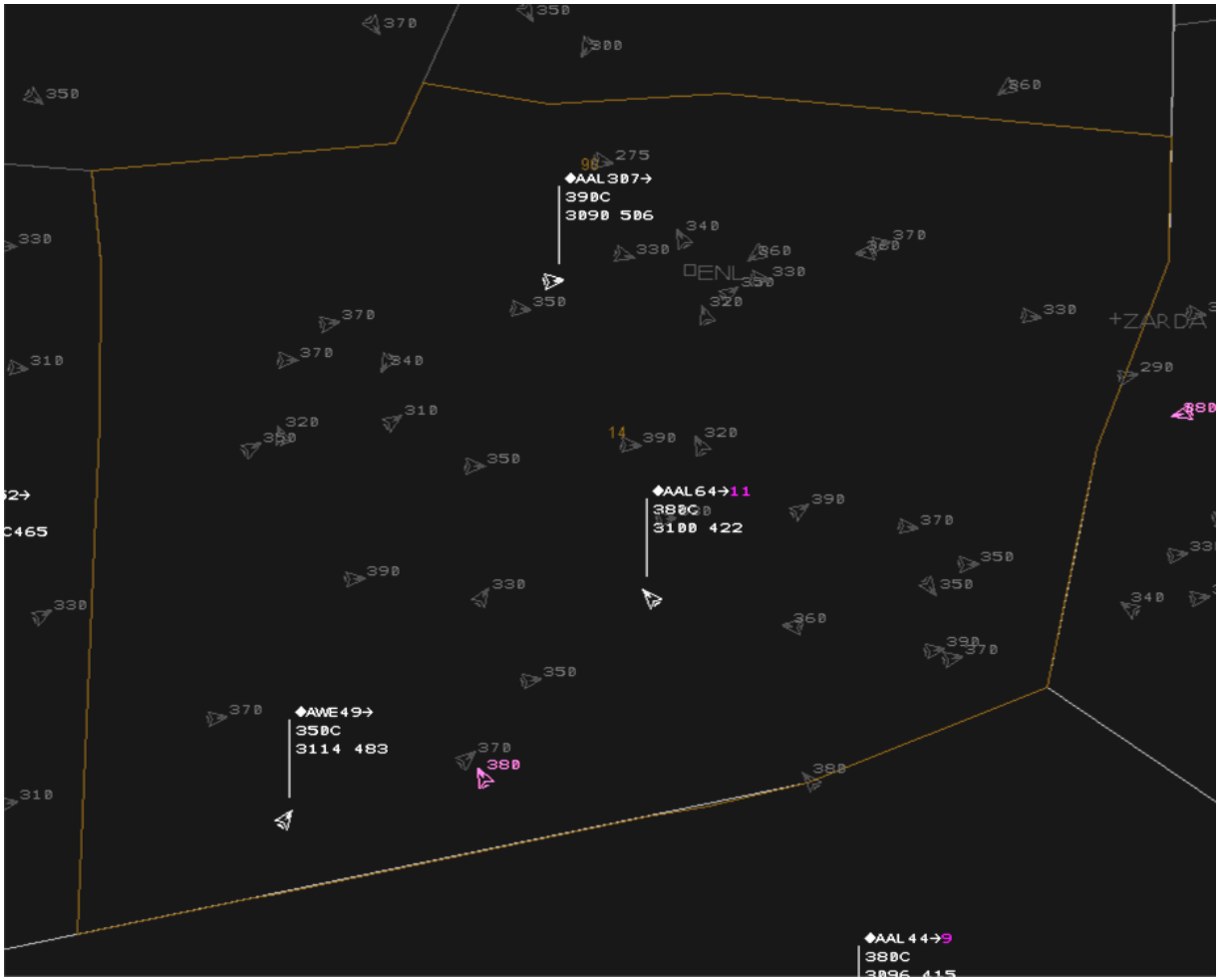
NASA Langley Research Center's Air Traffic Operations Laboratory (ATOL) team

The Problem



- NextGen is expected to accommodate a **threefold (3X) increase** in air traffic demand compared to today's levels
- Cognitive resources of air traffic controllers are **limited**
- Conventional clearance-based separation assurance (SA) is **not possible** in the envisioned high density environment

The Approach

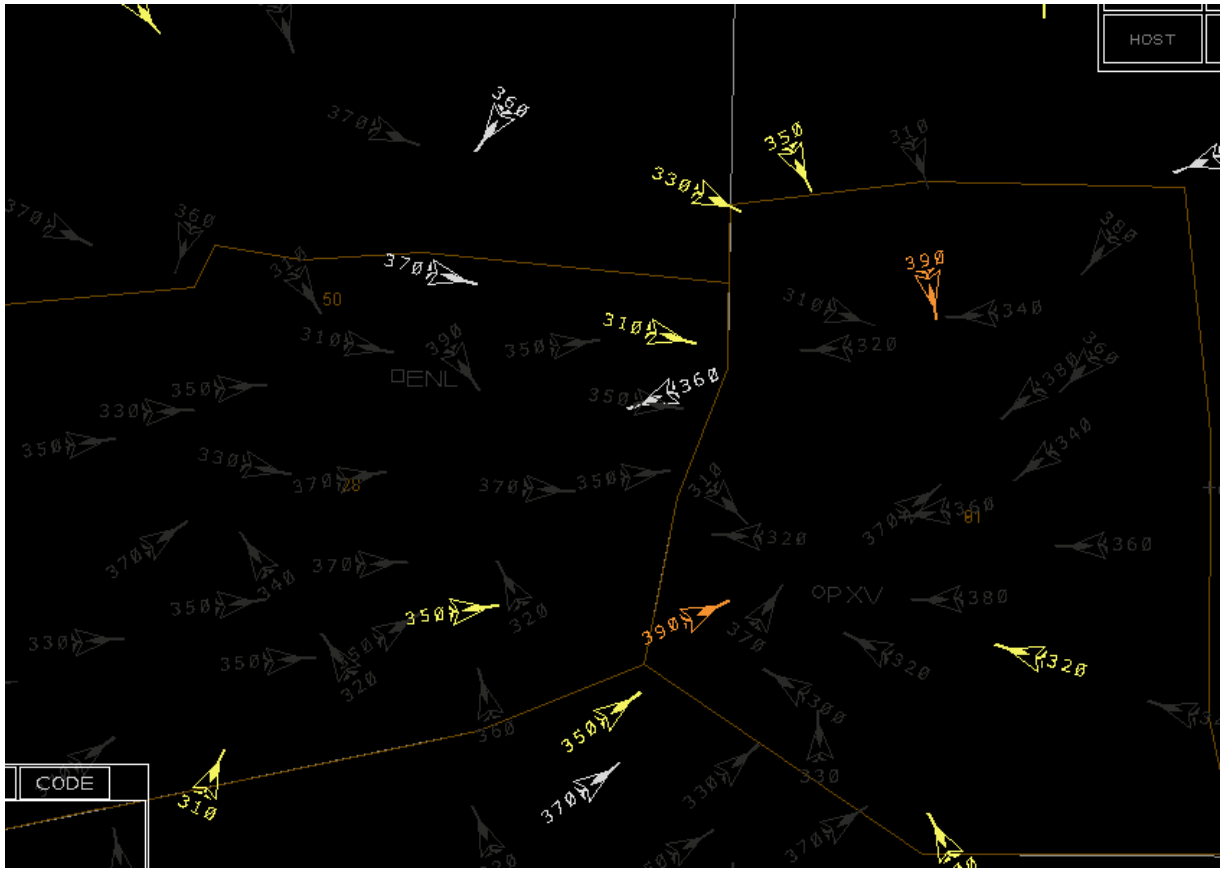


- "ground-based automated separation assurance"
- the ground-based *automation* manages the separation
- the *operators* manage the automation, provide additional services and make decisions

Airspace Operations Laboratory

Beginning in 2007, a series of HITL simulations on ground-based automated SA have been conducted in the AOL

SA1 (2007)

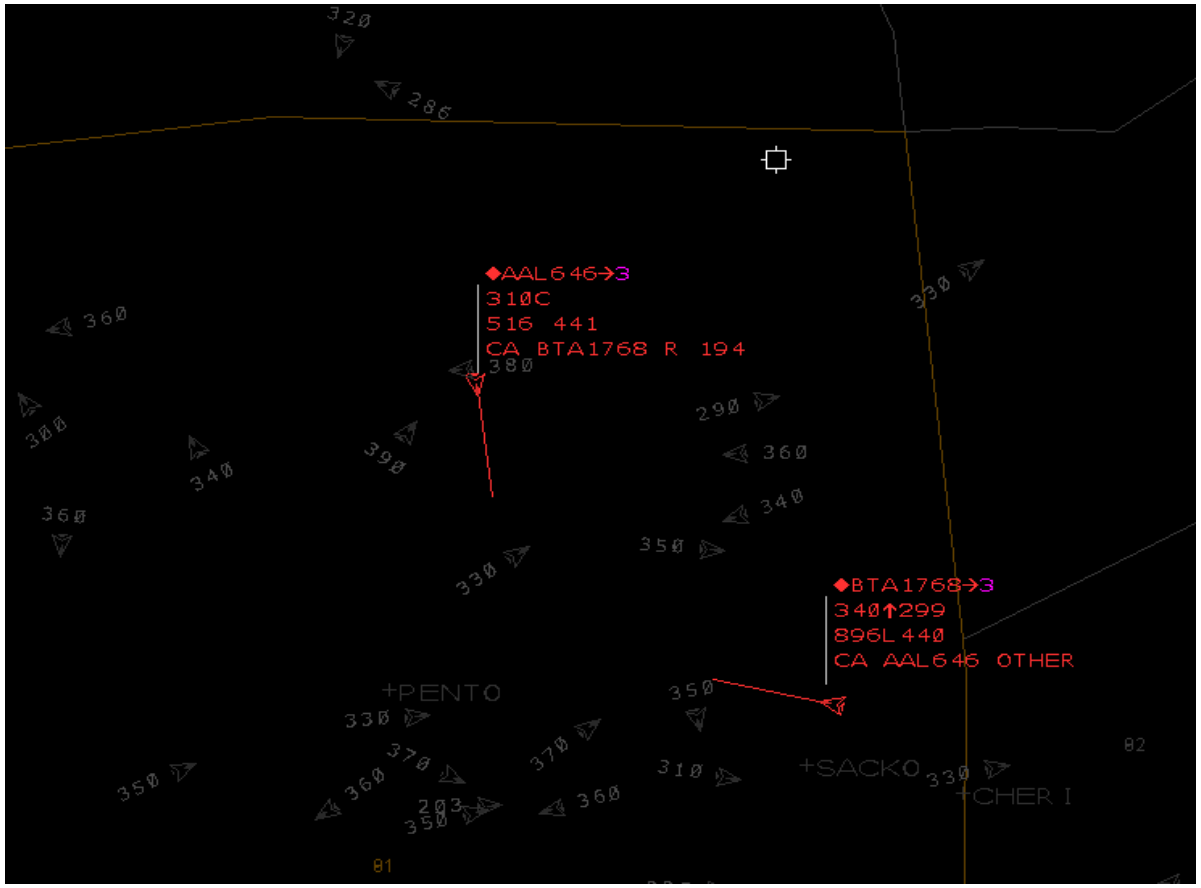


J. Homola, "Analysis of Human and Automated Conflict Resolution Capabilities at Varying Levels of Traffic Density". (Master's Thesis). San Jose State University, San Jose, California, 2008.

T. Prevot, J. Homola, and J. Mercer, "Human-in-the-Loop Evaluation of Ground-Based Automated Separation Assurance for NextGen". ICAS 2008-11.4.5, and AIAA-ATIO-2008-8885, Anchorage, Alaska, 2008.

- Tested SA at three progressive levels of traffic density:**1X, 2X, 3X**
- Varied levels of automated SA support across traffic levels: **Manual, Interactive, Fully Automated**
- Automation provided significant benefits in terms of safety and efficiency particularly at 2X and 3X. Significant reduction in workload. Resolutions provided by automation generally acceptable.

SA2 (2008)



T. Prevot, J. Homola, J. Mercer, M. Mainini, and C. Cabrall, "Initial Evaluation of NextGen Air/Ground Operations with Ground-Based Automated Separation Assurance". ATM2009, Napa, California, 2009.

J. Homola, T. Prevot, J. Mercer, M. Mainini, and C. Cabrall, "Human/Automation Response Strategies in Tactical Conflict Situations". DASC 2009, Orlando, Florida, 2009.

- Tested ground-based automated SA at **2X and 3X** with tactical conflict and off-nominal situations
- Varied levels of **TSAFE** support across traffic levels
- Automation handled strategic conflicts. Participants handled conflicts deferred by automation, tactical conflicts, pilot requests, and emergencies.
- 98% of strategic and 75% of tactical conflicts resolved by automation, 95% of resolutions acceptable to flight crew participants, workload generally low.

SA3 (2010) Background

- NASA's FY2010 ARMD Annual Performance Goal: "Conduct simulations of automated separation assurance with sequencing, spacing, and scheduling constraints."
- JPDO concerns regarding the "lack of clarity" surrounding the functional allocation of new functions and responsibilities between the ground-based ATC and flight deck-based systems.

SA3 (2010)

Two separate but collaborative studies on automated SA conducted from both the air- and ground-side perspectives in the ATOL and AOL

Poster created at NASA Langley for NASA Langley Center Team Award Ceremony on June 3rd 2010

D. Wing, T. Prevot, J. Murdoch, et al. "Comparison of Airborne and Ground-Based Functional Allocation Concepts for NextGen Using Human-In-The-Loop Simulations". AIAA, 10th ATIO, 2010.

Overall Experiment Design

Short duration runs

Timing of Arrival Time changes	
Basic (STA)	S1
Dispersed (one every minute)	S2
Synchronous (all at 6 or 8 minutes)	S3

Medium duration runs

Arrival Time Constraints	A	B
No (Baseline)	M1	M2
Yes (STA)	M4	M3

NextGen (Traffic) Level

Exploratory Long duration runs

Level of Traffic with Arrival Time Constraints	Growing	Decaying
Light	L1	L2
Heavy	L3	L4

Convective Weather Patterns

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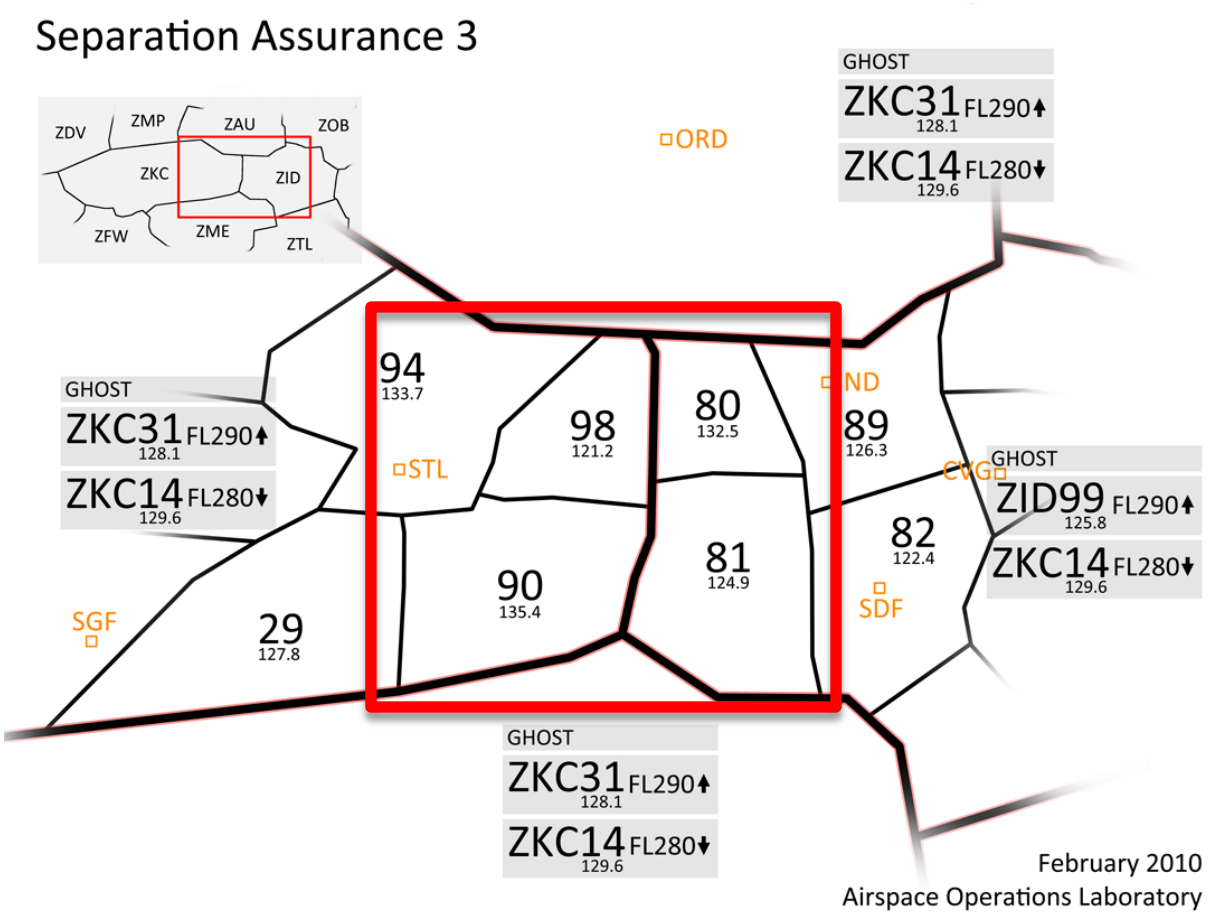
Convective Weather Patterns

Participants

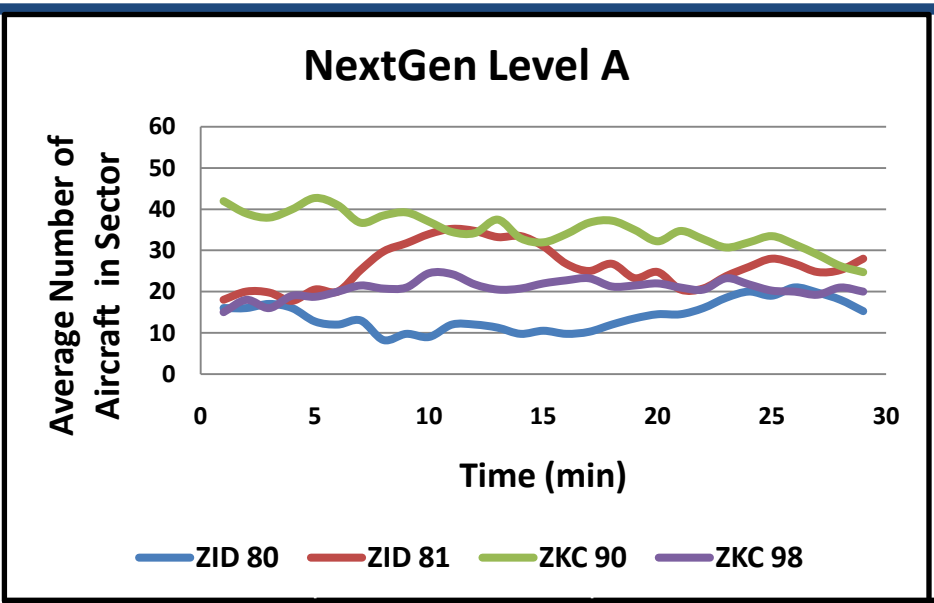
- Six FAA front line managers staffed radar and area supervisor test positions. They were from different en route centers and current on radar
- Four recently retired confederate controllers staffed remaining radar test sector positions
- Four retired confederate “ghost” controllers controlled traffic outside of test area
- Ten general aviation pilots served as pseudopilots for aircraft in the test scenarios

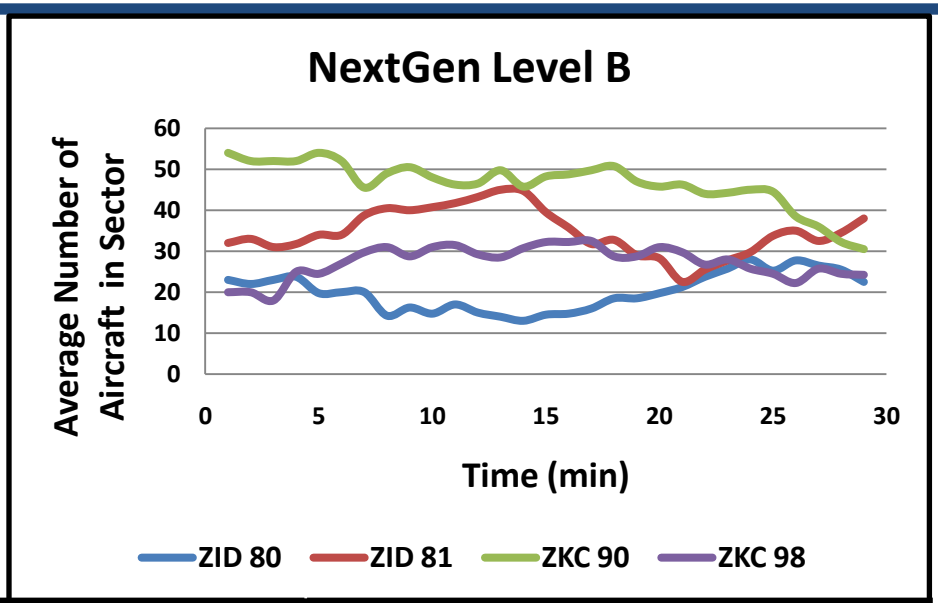
Airspace



- 4 en route test sectors from ZKC and ZID centers
- Surrounding airspace controlled by confederates
- Flight Level 290 and above
- Mixture of overflight and transitioning aircraft to and from area airports
- All aircraft fully data comm and ADS-B equipped

Air Traffic

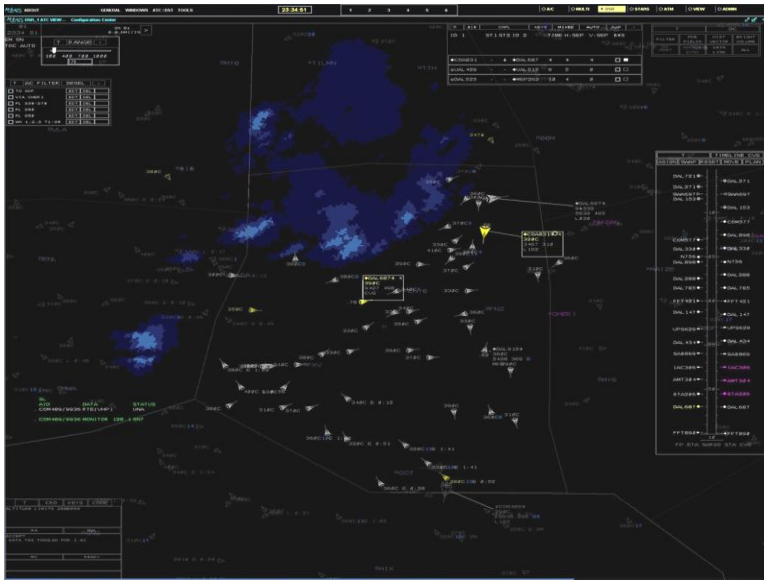




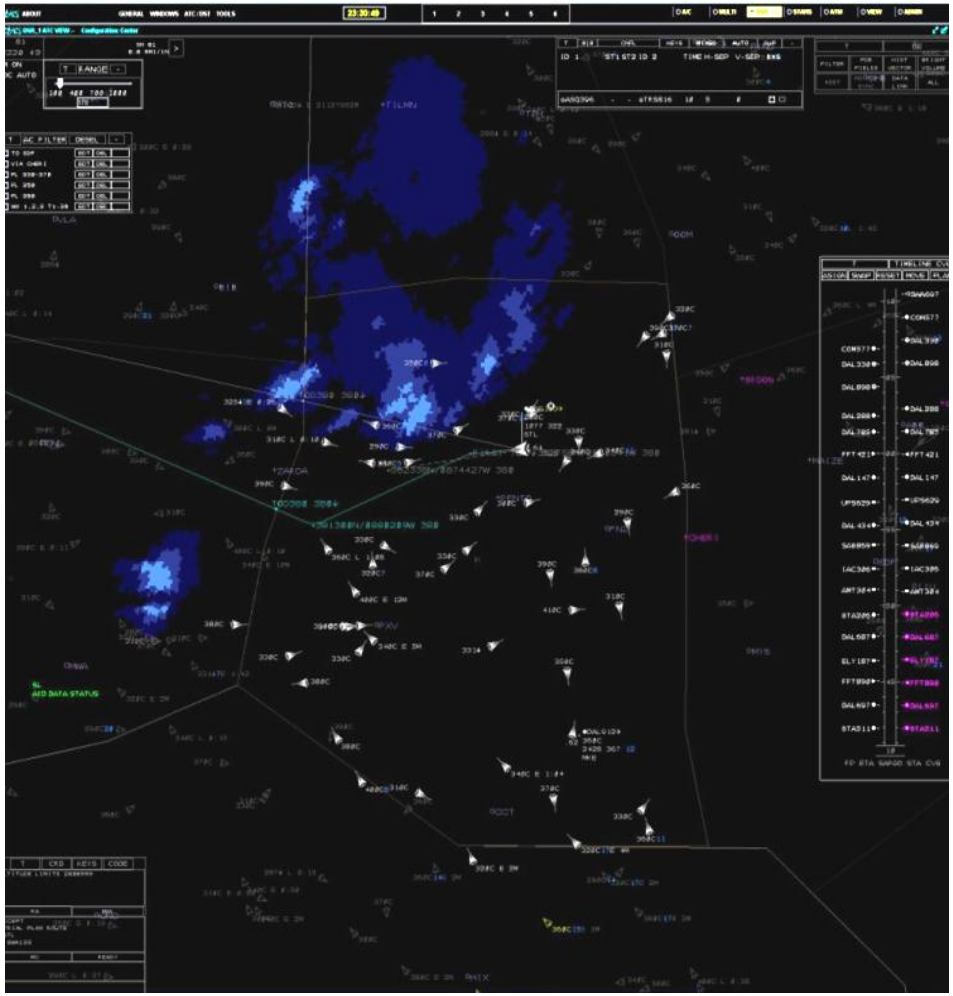
Traffic level	Forecast for year	Test airspace capacity		Aircraft in ZKC-90	
		Number of aircraft	% of 2010 value	Number mean/peak	% of 2010 value
	2010	108	100%	15 / 18	100%
NextGen A	2025	162	150%	35 / 42	233%
NextGen B	2030+	216	200%	46 / 54	300%

SA Functional Allocation

Automation	Controller
Detect Separation Conflicts	Supervise the automation
Resolve trajectory-based conflicts (if within tolerances)	Resolve trajectory conflicts flagged by the automation
Resolve all time-critical traffic conflicts	Monitor and maintain schedule compliance
Alert controller to urgent problems	Place aircraft back on trajectory following automated tactical maneuvers
Provide trajectory planning assistance	
Use data comm to communicate	

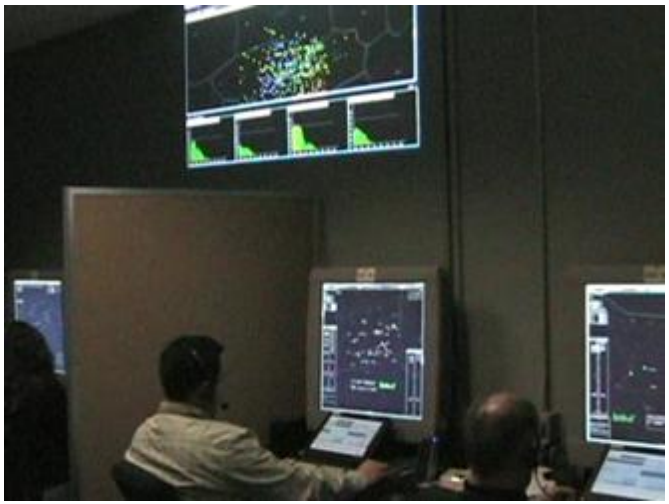


Apparatus



- MACS simulation platform
- Advanced controller displays
- 71 cm Barco displays
- DSR keyboards and trackballs
- Voice Switching and Comm. System (VSCS) emulation
- Wall projections of current and predicted traffic situations

Procedure



- Two week study
  - *Three days training*
  - *Five days data collection*
- 30-minute runs
- Participants divided into two teams
- Runs conducted simultaneously in two parallel “worlds”
- ZKC and ZID sectors divided within each world to ensure inter-facility coordination
- FAA test participants rotated through supervisor and radar positions for different perspectives

Results

— Airspace and traffic

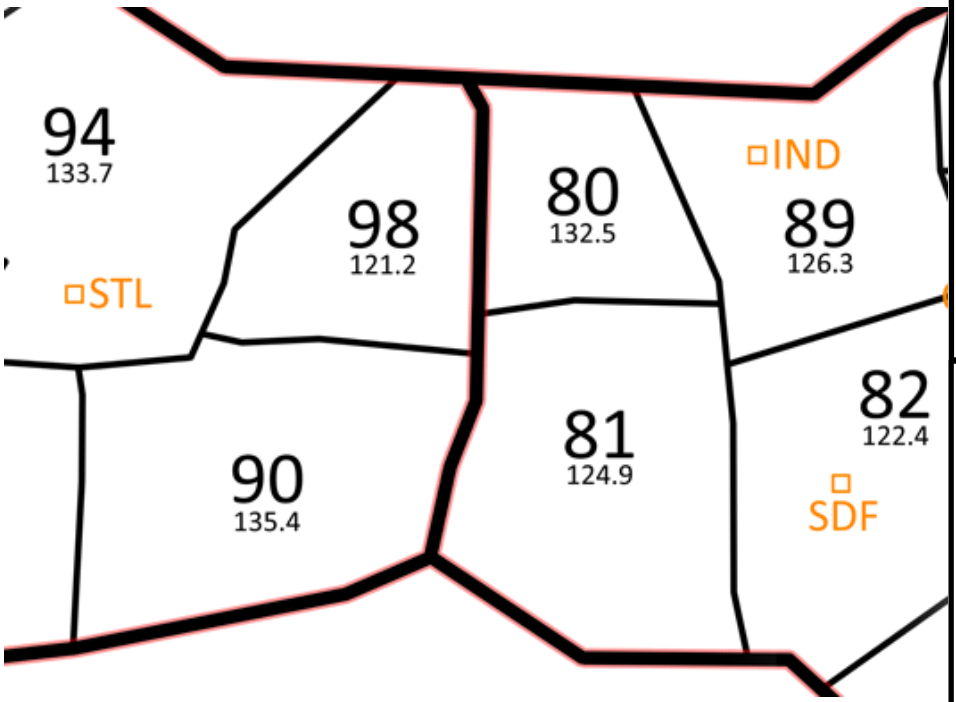
—Workload

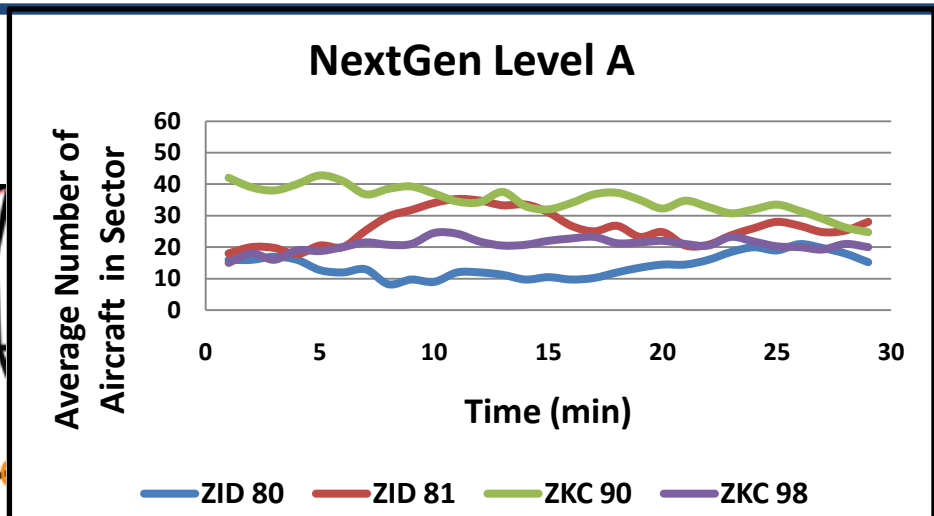
—Conflict detections and resolutions

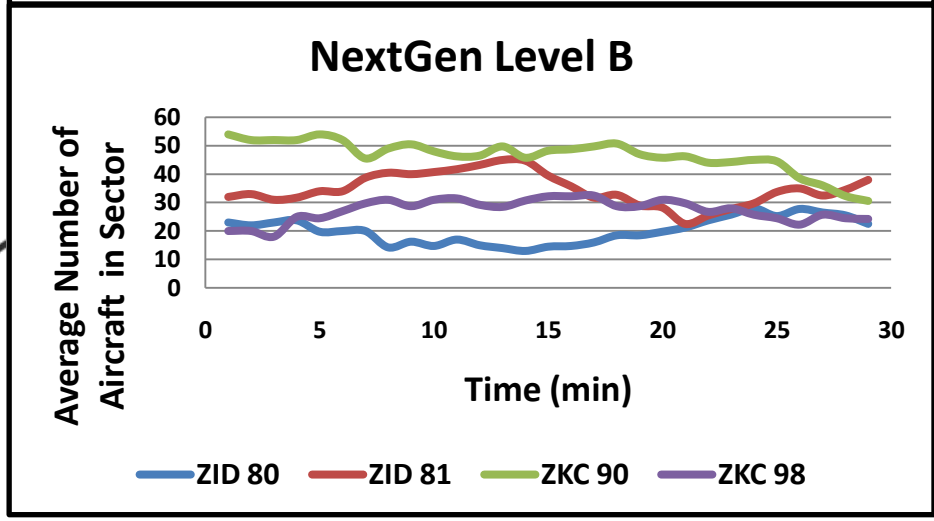
—Losses of separation

—Subjective participant feedback

Airspace and Traffic

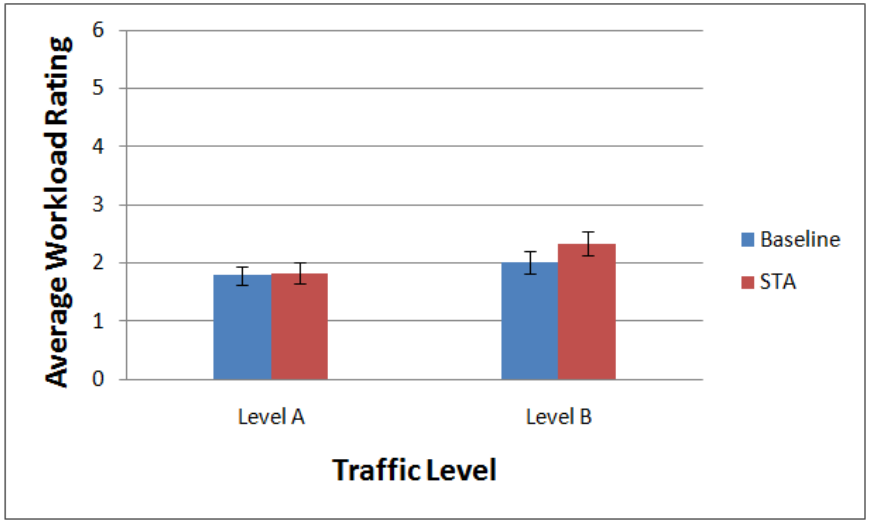




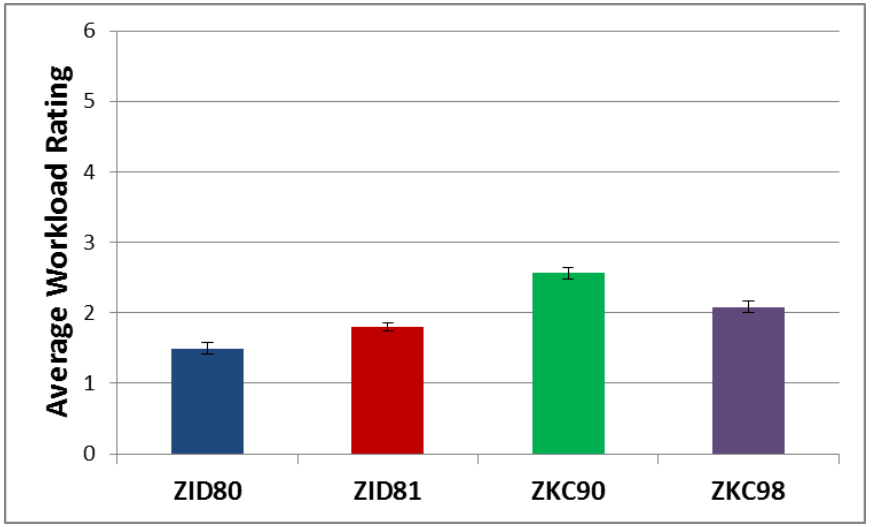


Workload

Workload by condition

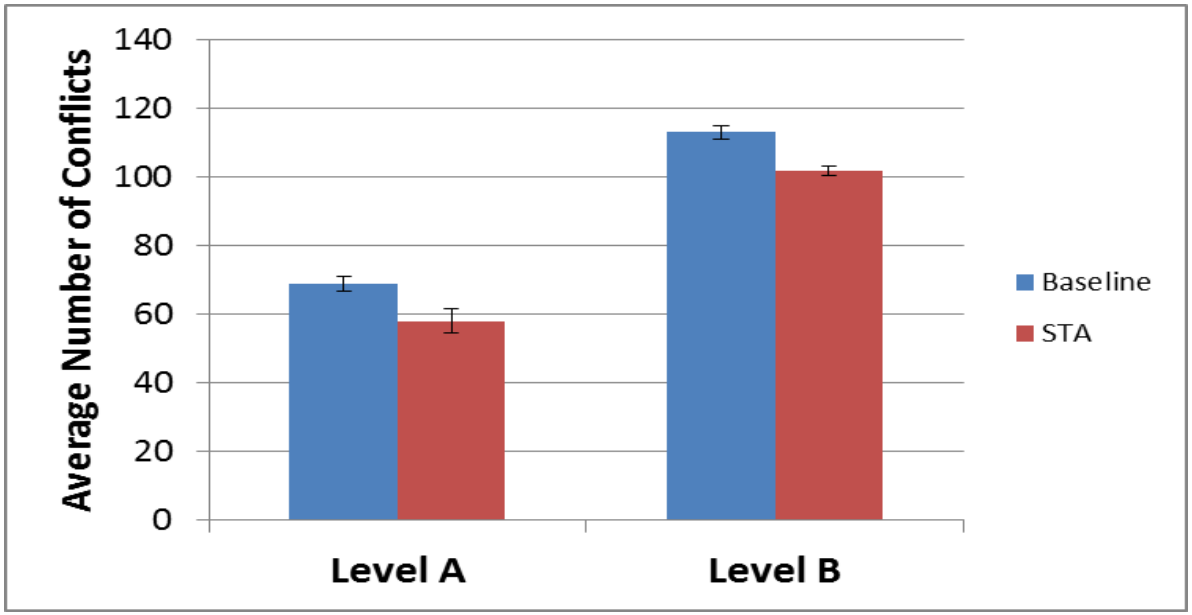


Workload by sector



- Workload significantly higher at Traffic Level B than Level A
- Scheduling constraints did not have an effect on workload
- ZKC90 had significantly higher workload than ZID80 and ZID81 **but not ZKC98**

Conflicts: Detections

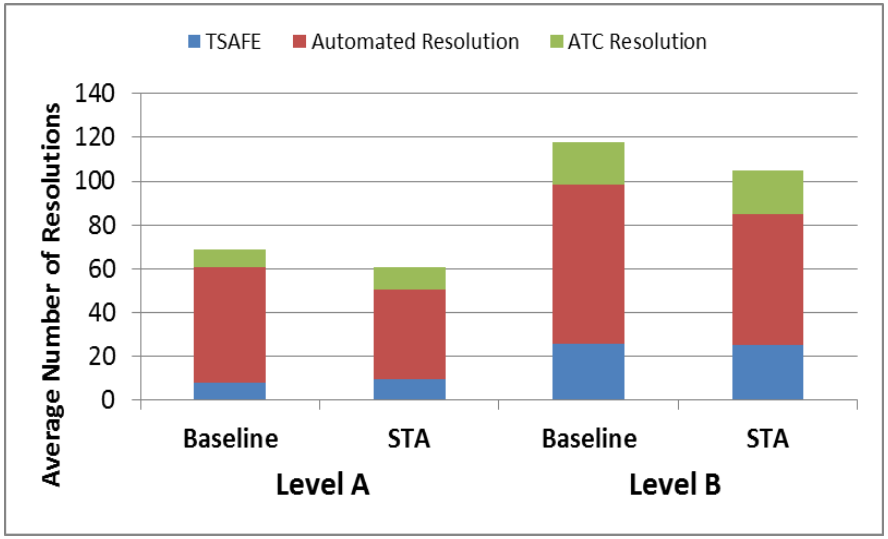


• Traffic Level B had significantly more conflicts predicted to lose separation in the test airspace than Level A

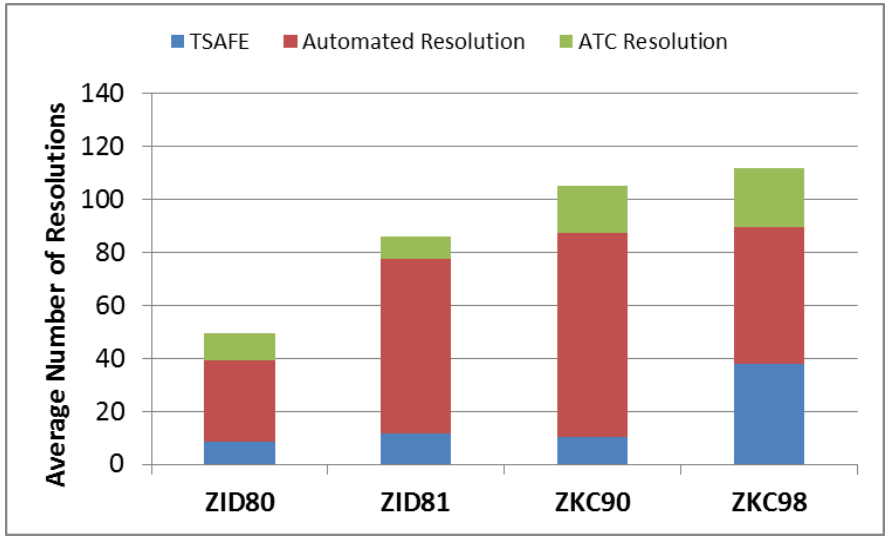
• STA scheduling condition had significantly fewer conflicts than the Baseline condition without scheduling constraints

Conflicts: Resolutions

Resolutions by condition



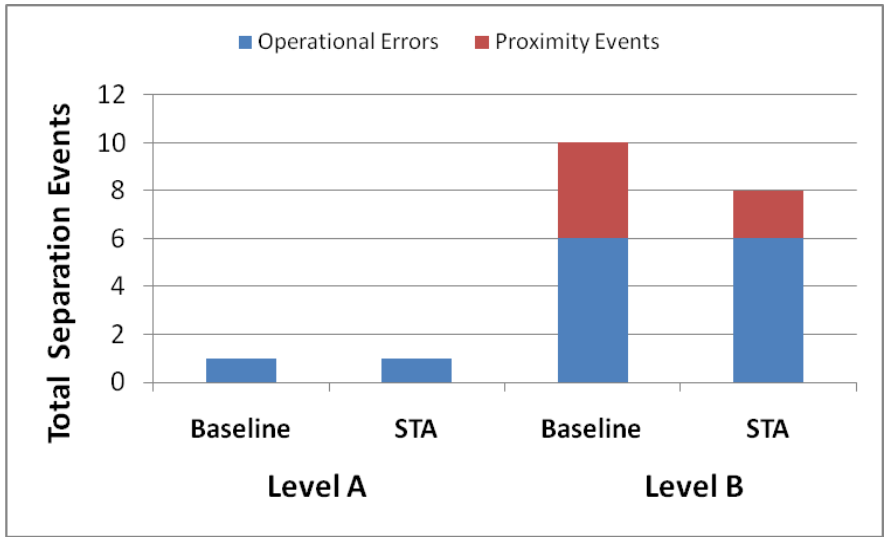
Resolutions by sector



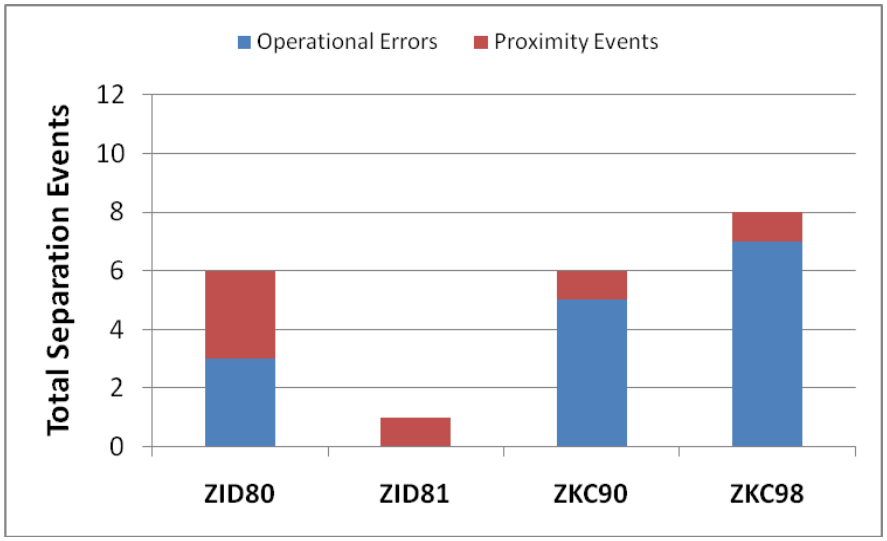
- Majority of conflicts resolved by automation
- ATC involved resolutions increased with traffic levels
- TSAFE events increased with traffic levels
- ZKC98 required the greatest number of conflict resolutions issued
- ZKC98 required greater ATC involved resolutions and TSAFE clearances

Losses of Separation

Events by condition

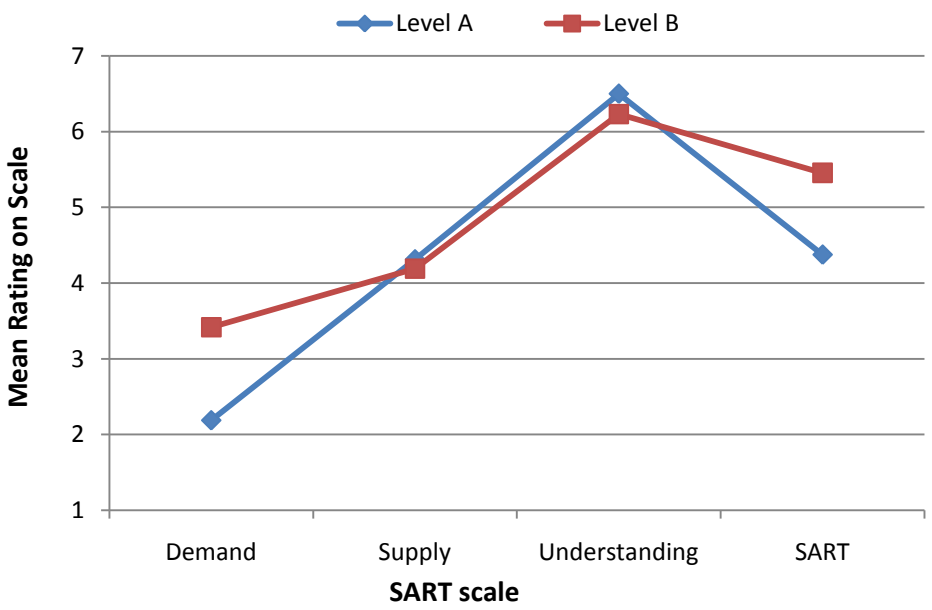


Events by sector



- Traffic Level B resulted in greater numbers of separation events
- Baseline and STA conditions resulted in equal numbers of operational errors
- Baseline had overall greater number of separation events
- ZKC98 had the greatest number of separation events followed by ZKC90

Subjective Feedback: Situation Awareness



Situation Awareness Rating Scale

- Spread of responses both between traffic levels and sectors
- "A little" attention demand
- "Average" supply of attention
- "Very good understanding" of situation
- **"Reasonable situation awareness"**

Subjective Feedback: Acceptability

- Questions on acceptability of operations aligned with Controller Acceptance Rating Scale (CARS)
- Acceptability of safety in Traffic Level A rated at 90.6% and Traffic Level B at 67.5%
- Volume of traffic not a concern but the greater complexity of the traffic and fewer resolution options were

Subjective Feedback: Impressions

- "…it seemed as if controller and automation fought against each other at times to resolve conflicts."
- "it seems fairly natural, why not do it?"
- "You're on the right track."
- **"It's inevitable, I think the concept is strong, it needs work and testing, I think it's the way we're going to go."**

Summary

- Increase from Traffic Level A to B provided the most noteworthy results
- Mean workload, conflicts detected, and losses of separation counts were all higher in Level B
- “Reasonable situation awareness” was maintained at both traffic levels but Level B was rated as less safe (CARS) and more attention-demanding (SART) than A
- At the sector level, local complexity more of an issue than simple aircraft count (e.g., ZKC98)

Conclusion

- The functional allocation of separation assurance between controller and ground-based automation presented was well received and held promising results
- An important component to being able to accommodate the envisioned future demand is the appropriate identification and handling of local complexities

Questions?